Chirp Sonar Investigation of the Eel River Subaqueous Delta and Surrounding Shallow-Water Regions, Offshore California

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LONG-TERM GOAL

Our long-term goal is to unravel the complex interplay of processes responsible for strata formation across a variety of scales. The dynamics linking short-term sediment input, dispersal, and accumulation and the formation of the longer-term stratigraphic record must be understood in order for us to construct realistic quantitative stratigraphic and morphologic models for shallow water regions.

OBJECTIVES

Our main objective is to determine the relationship between the Eel and Mad river systems, their subaqueous deltas, and the surrounding shallow water regions offshore Northern California in order to evaluate the importance of sediment input and dispersal, tectonic deformation, eustasy, and physiography in the formation of the stratigraphic record. Furthermore, by examining the spatial and temporal link between rapid, short-term accumulations on the shelf (e.g., flood deposits) and longer-term accumulations, we will begin to understand the processes that govern sediment redistribution and preservation.

APPROACH

We conducted a geophysical survey of the shallow water shelf regions (~20 - 70 m) offshore of the Eel and Mad Rivers, Northern California, onboard the R/V Coral Sea in September/October, 1998. We used a new state-of-the-art shallow water acoustic imaging system (SUBSCAN) to define the variability of the surficial structure, stratigraphy, and morphology of the region. SUBSCAN, a Chirp seismic reflection and side-scan system, images both the seafloor and subbottom sedimentary layers in shallow water environments. The subbottom Chirp system sweeps across a broad frequency band (0.5-16 kHz). Several different frequency pulses are available depending on the substrate and desired subbottom resolution. The side-scan sonar is a dual frequency (100 & 500 kHz) Edgetech DF1000 system. SUBSCAN can acquire data in the following modes: (1) flown in a traditional configuration while maintaining a constant depth above the seafloor, (2) towed across the bottom in a tow-sled, or (3) suspended from a cata-raft approximately 0.5 meters below the sea surface.

WORK COMPLETED

Research and development were completed on SUBSCAN along with other cruise preparations.

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After overcoming initial equipment problems, our cruise was a success. We collected approximately 1050 km of dual frequency side-scan (100 & 500 kHz) and high resolution Chirp data along the inner California shelf (Figures 1 and 2). The acquired sides-scan images provide data along the inner shelf that complement the EM1000 data collected along the California margin in 1995 by L. Mayer and others. This new data extends our swath coverage landward to the 20 m isobath and in some areas to the 8 m isobath. In addition to acquiring data offshore, we also mapped the structure, stratigraphy, and morphology in Humboldt Bay to determine if the paleochannels and fault structures mapped on the inner shelf extend landward.

Data analysis is proceeding and the 100 kHz side-scan mosaic will be combined with the EM1000 backscatter data from the region.

RESULTS

Numerous surficial failures were observed in the side-scan data on slopes averaging less than one degree. In addition to the failures, high and low reflectivity patches (blotchy seafloor) on the seafloor, and pock marks 25-50 m in diameter were observed. The regions of blotchy seafloor and pock marks were often associated with high reflectivity clouds in the water column observed in the side-scan data between nadir and the first seafloor arrival as well as with high reflectivity regions in the Chirp subbottom data. Underwater video and recently acquired ROV data (October 1998) indicate that these high reflectivity clouds are caused by gas in the water column. The failures and blotchy seafloor appear to be spatially related to the Eel and Mad River subaqueous deltas, which consist of coarse-grained deposits and have an unexpectedly low backscatter amplitude.

The intervening region between the subaqueous deltas is relatively devoid of pock marks and blotchy seafloor in the side-scan data, and is characterized by shore-perpendicular streaks of low backscatter imaged in both the 100 and 500 kHz side-scan data. High frequency (0.5-16 kHz) chirp seismic data were collected concomitantly with the side-scan data across the shelf and routinely imaged ~30+ m into the subbottom. In the region between the subaqueous deltas, numerous subbottom reflectors at a variety of depths were consistently imaged (Figures 1 and 2). In fact, a pronounced anticline is imaged between the subaqueous deltas and appears to be the landward continuation of the Little Salmon Anticline observed offshore on the lower slope. The crest of the anticline is buried by approximately 3 meters of sand and in some areas a southward dipping fault appears to continue up into the overlying carapace (Figure 1). The style and nature of the anticline changes dramatically along strike; from being obscured by gas offshore (Figure 2), to being a text-book example of an anticline in shallower water. Preliminary analysis suggests that this fault/fold structure continues onshore and crosses Samoa Beach and northern Humboldt Bay and appears to extend under the City of Eureka.

Moving away from the crest of the observed anticline (Figure 1) the overlying sedimentary succession thickens both toward the Mad River syncline and toward the Eel River Syncline (Figure 2). The sedimentary layers onlap the structural high indicating that the layers are thinning by nondeposition rather than by erosion. The thickness of the overlying carapace increases from approximately 3 m near the crest of the anticline to greater than 45 m near the axis of the Eel River syncline. Age dating and further mapping will provide new insights concerning the tectonic control on the long-term accumulation offshore California.

The amplitude of the reflectors decreases markedly near both the Eel and Mad River subaqueous deltas. Across the subaqueous deltas themselves, there are no observed reflectors. In this region, only a very

diffuse scattering layer ~5 meters below the seafloor is observed as well as intermittent highly reflective 'bright' zones. On the basis of the pock marks and blotchy seafloor, subbottom acoustic character, and gas seeps, we propose that shallow gas may be an important contributor to failures observed on the subaqueous deltas.

Paleochannels are also observed in the Chirp data offshore Somoa Beach just to the north of the Little Salmon Anticline. The paleochannels suggest that the mouth of Humboldt Bay was located farther north in the past or they may be recording the location of the antecedent Mad River. Further seismic correlation and research is required to understand the importance of the observed paleochannels.

IMPACT/APPLICATION

New images of the shallow fold and fault structures offshore Northern California will improve our understanding of the tectonic deformation and how it governs long-term accumulation along the margin. In addition, defining the distribution of fold and fault structures in the region might potentially help mitigate earthquake hazards.

The paleochannels observed in the Chirp data suggest that the mouth of Humboldt Bay was located farther north in the past. These paleochannels may also be recording the location of antecedent rivers (e.g., Mad River). A better understanding of inlet and channel migration is the critical first step to deciphering preserved strata in shallow water regions.

Finally, shallow gas release may be an important process contributing to failures observed on the subaqueous deltas. Earthquakes and excess pore-pressure caused by rapid sediment accumulation may be potential triggers of gas release which might explain the occurrence of failures on such low angle slopes.

TRANSITIONS

Results from our cruise concerning gas seep locations were used to collect gas samples along the Eel River margin by an ROV cruise conducted during late October, 1998 by Lisa Levin and Kevin Brown (SIO).

Our new SUBSCAN system will also be used to conduct feasibility studies for biological acoustic imaging (T. Stanton, WHOI).

The USGS is interested in using the new SUBSCAN to image other shallow water regions offshore California (e.g., San Francisco Bay) to define shallow fault zones.

RELATED PROJECTS

The goals of this project interface with the objectives of a number of ongoing and proposed research projects within the ONR STRATAFORM Initiative both on the east and west coast of the United States. Furthermore, by imaging shallow-water stratigraphy we will improve our understanding of processes that transfer sediment, sculpt the continental margin, and create stratigraphic sequences, insight that can be applied to other littoral zones throughout the world.

PUBLICATIONS

N.W. Driscoll, D. L. Orange, J. Yun, L. Fonseca, and L. Mayer, 1998. High Resolution Side-Scan and Seismic Images of Landslides on the Northern California Continental Shelf. Abstr. EOS Transactions Fall Meeting.

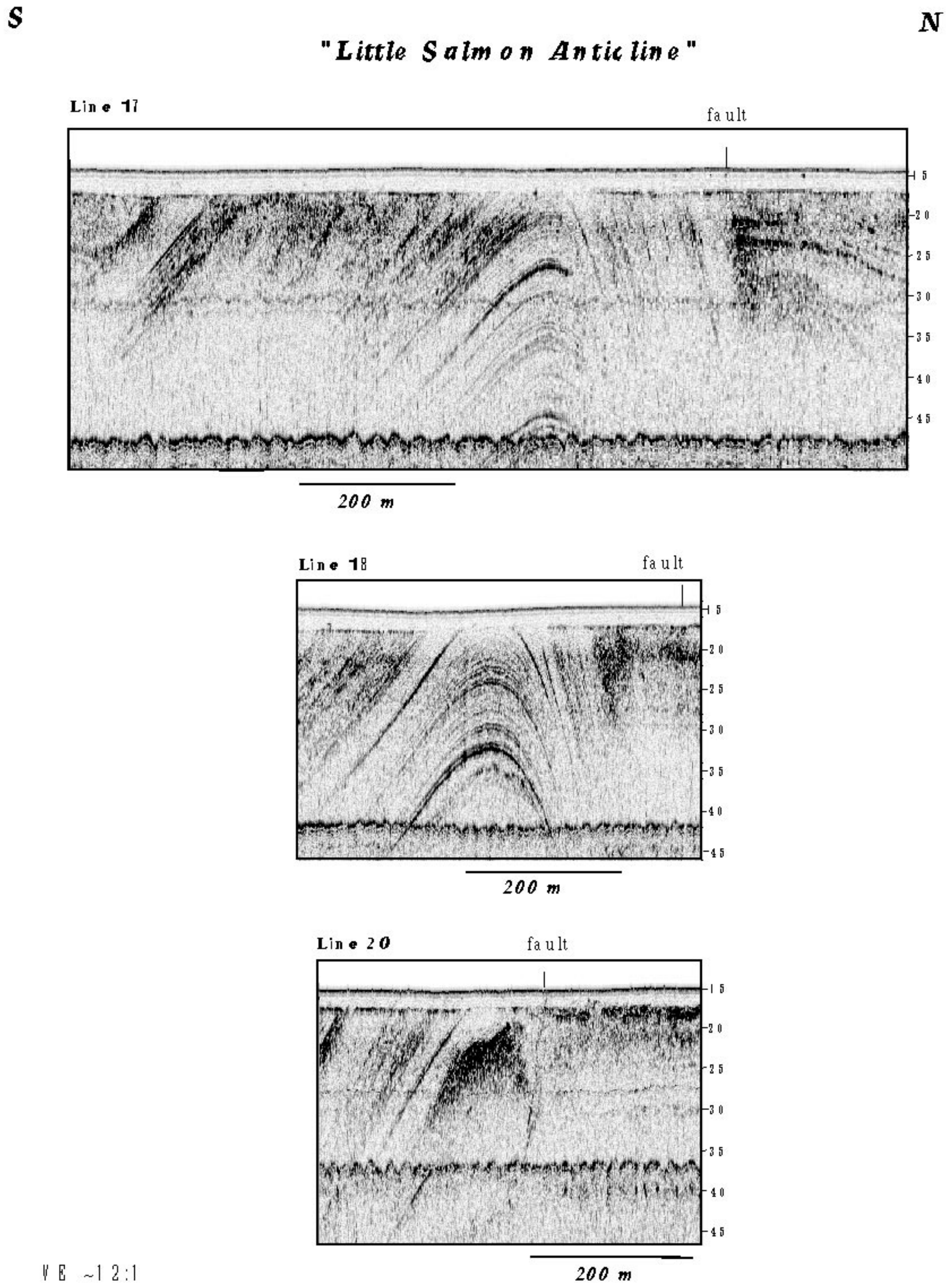
S
N
"Little Salmon Anticline"
Line 17
fault
200 m
Line 18
fault
200 m
Line 20
fault
200 m
VE ~12:1

Figure 1

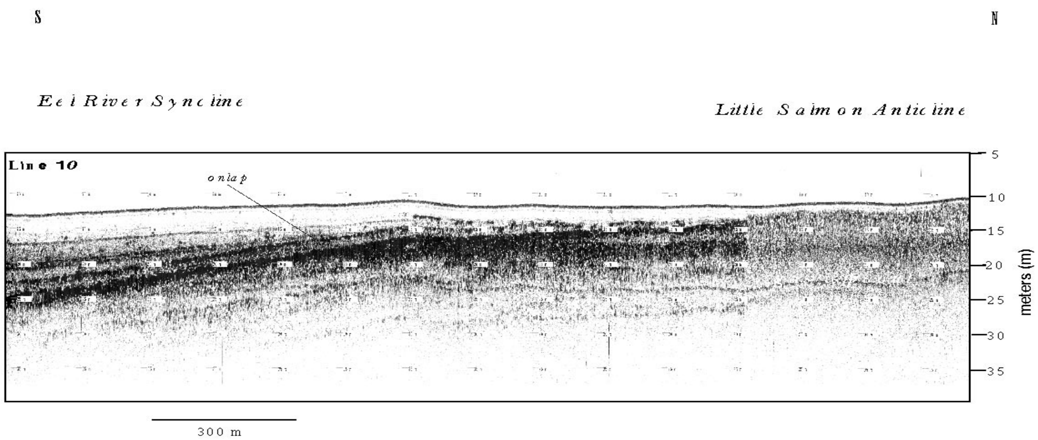
S
N
Eel River Syncline
Little Salmon Anticline
Line 10
onlap
5
10
15
20
25
30
35
meters (m)
300 m

Figure 2